VCP Calibration
ORDA Design White Paper

ORDA Systems Engineering

Introduction

The NEXRAD SS requires three calibration measurements during each volumetric scan sequence and associated automatic correction to the base data during the subsequent scan. The measurements are made to guarantee that the RDA equipment is operating within all specified parameters on a scan-by-scan basis. ORDA design engineers, working with ROC engineers, are proposing a new set of checks to completely satisfy the NEXRAD SS requirements and to guarantee the data quality of radar base moments. The tests proposed include a subset of legacy tests performed every VCP in addition to a new set of tests developed specifically for the ORDA system design. Improved linearity and dynamic range test, noise and noise temperature checks, transmitter power measurements, burst pulse diagnostics, and processor diagnostics measure the data quality of the system on a scan-by-scan basis. The combination of these tests confirms proper system operation from the first active component through the signal processor output. As a result, we recommend decreasing the frequency of the legacy implementation of the velocity/spectrum width check to every Performance Check (typically 8 hours). This paper will describe the NEXRAD requirements and describe how the ORDA calibration tests and alarms will provide increased confidence in the data quality of the radar base moments.

NEXRAD Requirements

Section 3.7.2.11 (Calibration) of the NEXRAD SS (document number 2810000) states:

> The RDA shall (1), during each volumetric scan sequence, automatically perform the calibration measurements defined in this section and automatically correct the measurement of base data in the subsequent volume scan.
>
> The calibration data and parameters shall (2) be included in the RDA status data which accompanies base data for applications by the users at all levels of data processing.
>
> RDA performance data shall (3) be incorporated into the digital information message traffic provided to the RDA HCI, the RPG and the FAA RMS, and shall (3a) be displayable at the RDA maintenance interface.
>
> The calibration measurements include but are not limited to the following:
>
> a. A measurement of the average transmitted power level shall (4) be monitored.
>
> b. A calibration of the RDA reflectivity channel from the channel's first active device through the signal processor shall (5) be monitored. This calibration shall (6) be timed to correspond to regions of space devoid of both ground clutter and weather echoes. The calibration shall (7) be performed over the entire linear range of performance. The calibration signals shall (8) undergo the same averaging as the weather echoes.
>
> c. The mean radial velocity and spectrum width processing performance shall (9) be monitored. This monitoring function shall (10) be timed to correspond to regions of space devoid of both ground clutter and weather echoes. This monitoring function shall (11) include at least one known value of mean radial velocity and spectrum width at one range cell.

Design

The ORDA system will perform the following lists of tests every VCP – note that in some cases, the check is performed on a per radial basis to provide higher confidence in system operation:

a. Transmitter Average Power

SS: A measurement of the average transmitted power level shall (4) be monitored.

The RDA uses the average transmitted power as an input to the weather equation (in terms of peak power) and for display and monitoring. The average power is used to compensate for long-term drifts in the transmitted power, which assists in accurate reflectivity computations.

In the legacy and ORDA system, the Transmitter Power and Power Meter Zero tests will be performed similarly. A running average of the transmitted power shall be measured with a power meter and input to the SIGMET processing software. This measurement will be made periodically during each cut within the volume scan sequence. Recorded values will be averaged together. A final average and peak power value will be computed at the end of every cut and will be provided to the SIGMET processing software for inclusion in the weather equation. Any deviations will be detected and an alarm flagged. The power meter will be calibrated to zero during the retrace period at the end of every VCP.

b. Reflectivity Calibration

SS: A calibration of the RDA reflectivity channel from the channel's first active device through the signal processor shall (5) be monitored. This calibration shall (6) be timed to correspond to regions of space devoid of both ground clutter and weather echoes. The calibration shall (7) be performed over the entire linear range of performance. The calibration signals shall (8) undergo the same averaging as the weather echoes.

The reflectivity calibration consists of system noise, noise temperature, receiver linearity and receiver dynamic range measurements. The goal of the tests is to identify any equipment and/or processing failures and provide correction factors for the base data computations.

The noise and noise temperature tests, computed exactly as the legacy design, provide confidence in the proper operation of the receiver chain, including the IFD and signal processor. Noise measurements provide the best indication of failure in the receiver path. Any failures in the IFD A/D are easily detected with this test.

The legacy design did not check the full linear or dynamic range of the receiver path. Legacy calibration tests performed a spot-check with four test signals:

1. RF Drive signal at approximately 80dBZ at 44 km range for short pulse and 20 km for long pulse
2. RF Drive signal at approximately 60dBZ at 78 km range for short pulse and 134 km for long pulse
3. RF Drive signal at approximately 55dBZ at 112 km range for short pulse and 227 km for long pulse
4. Constant power Continuous Waveform processed from range of 5 to 145 km

ORDA's staggered linearity test performed every VCP, will check the entire range periodically. That is, each VCP will execute 10 points on the linear curve. The 10 points will be interlaced with data from subsequent VCPs to compute the entire linear range. For example, the first VCP will use points 1, 11, 21, 31 …, the second VCP will use points 2, 12, 22, 32 …, and so on. The ORDA design will test the entire linear range every Performance Check.

In addition, the ORDA design will perform a dynamic range test every VCP. The dynamic range test will start at an estimated point 10dB below the 1dB compression point and will inject a test signal in 1dB steps until the 1dB compression point is detected. Subtracting the noise value previously measured from the 1dB compression point value will result in the system dynamic range.

Finally, ORDA will compute a reflectivity correction factor dBZ_0 (formerly called SYSCAL) every VCP. This calibration will provide an adjustment for the reflectivity computation. Known test signals will be input to the receiver chain and the resultant reflectivity moment will be compared against an expected value. Alarms will be generated based on the difference of the two values. This test checks the entire receiver path and the moment computations in the signal processor.

c. Velocity & Spectrum Width Check

> *SS: The mean radial velocity and spectrum width processing performance shall (9) be monitored. This monitoring function shall (10) be timed to correspond to regions of space devoid of both ground clutter and weather echoes. This monitoring function shall (11) include at least one known value of mean radial velocity and spectrum width at one range cell.*

The ORDA design uses the burst pulse input to the IFD as the phase reference for velocity and spectrum width computations. This signal is continually monitored internally in the RVP8 software and failure diagnostics are provided on a radial-by-radial basis. The SIGMET software measures both the burst phase difference between the current and previous pulse and captures (I, Q) data for the instantaneous burst pulse.

The legacy velocity/spectrum width check phase shifted the COHO reference clock output from the RF generator to simulate a test velocity/spectrum width. Based on the commanded frequency shift, an expected velocity/spectrum width value was compared against the computed velocity/spectrum width. Only four velocities (zero, ¼ nyquist, -3/8 nyquist, & 5/8 nyquist) were simulated to verify the performance of the A/D converter, RF Frequency generator phase shifter, and signal processing hardware. In the ORDA design, the A/D converter and signal processing hardware are verified through the exhaustive receiver checks; therefore, only the RF Generator Phase Shifter is not tested. But this component is not used during normal operation and was only used in the legacy design to perform this test.

Nevertheless, a case for the need to check the RF Generator Phase Shifter can be made for future enhancements such as phase encoding. There are essentially two options to guarantee the integrity of the RF Generator Phase Shifter. One would be to calibrate and measure the repeatability of the phase shifter. The second is to simply measure the phase of the signal on a pulse-by-pulse basis. The SIGMET processors use the second technique. Given a commanded phase, the actual phase is measured with the burst pulse. The actual measured phase is used in the computations. In case a discrepancy is detected between the commanded and actual phase, an alarm would be flagged to indicate system degradation. The advantage of this method over the first option is the fact that fairly reliable data is still available because the actual measured phase is used as the reference value in the computations for velocity and spectrum width. Therefore, the system can continue to be operational until the RF Generator Phase Shifter can be replaced.

In the history of the WSR-88D program, only 11 failures relating solely to the velocity/spectrum width alarm have been documented by the Hotline. Of these 11, 5 were test path problems, 1 was an A/D failure, 1 was a receiver channel alignment error, 2 causes were never found, and 2 were Signal Processor hardware failures (1 was simply reseating a board in the PSP). Only 1 (the Signal Processor problem with an AU card in the PSP) of these 11 failures affected the products. Of the nine instances in which a specific cause was identified, the ORDA fault detection and/or calibration checks will detect those failure conditions and alert the technician.

Conclusion

Given the stability of the velocity/spectrum width components in the ORDA design, the fact that failures in these components are better detected with other calibration tests and the enhanced internal SIGMET monitoring capabilities, ORDA recommends that the legacy-designed velocity/spectrum width test be either 1) performed only during the Performance Check, or 2) eliminated. ORDA and ROC Engineering agree that the requirement for a specific velocity/spectrum width check during each VCP be removed from the SS and replaced with a general requirement stating that the entire transmit/receive chain (from the first active component to the output of the base moment data) must be checked every VCP. This requirement is addressed by the ORDA design; thereby guaranteeing the proper operation of the radar system.